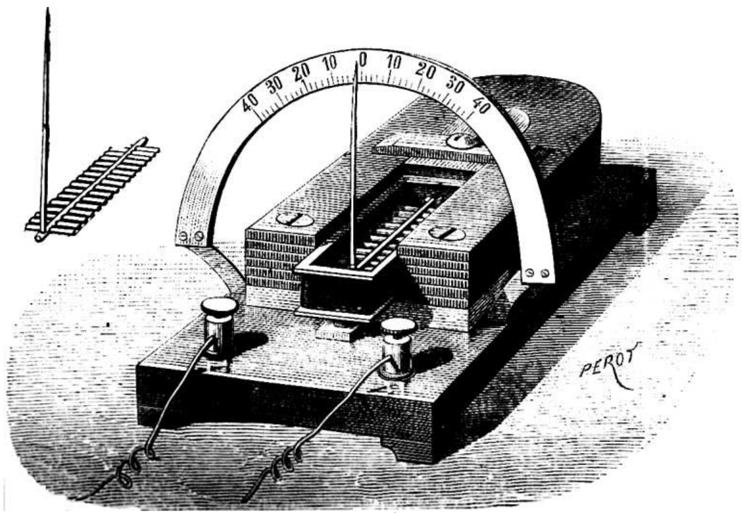
terminals are joined to the two ends of an insulated wire, part of the length of which is laid parallel and near to the conducting-wire of the dynamo-electric machine. M. Deprez's new galvanometer shows by the most direct evidence that this is the case, for when inserted in the circuit of any dynamo-electric machine its needle is observed to be in incessant vibration.

The only instrument constructed previously to that we are about to describe, suitable for measuring strong currents, was the tangent galvanometer of Dr. Obach, the essential feature in which consisted in the conducting-ring being made movable about a horizontal diameter, and therefore capable of being adjusted by inclining it at a greater or less obliquity to any degree of sensitiveness between its maximum and zero, the horizontal component of the magnetic force of the current circulating in it being zero when the ring was laid over into a horizontal plane.

M. Deprez's galvanometer is, however, a much more handy instrument, its indications are almost instantaneous, and the deflections with very strong currents are not unreasonably great. To secure this end it has been necessary to make the needle of the instrument very light, and at the same time to give it a very great directive force by placing it in an artificial "field" of very great intensity. The needle consists of twelve or fifteen little pieces of soft iron wire set side by side transversely



Marcel Deprez's Galvanometer for very strong currents.

upon an axis of brass which is supported between two pivots. The axis carries also a light hand or index of straw or aluminium fixed at right angles to the little iron needles. This compound needle is placed between the limbs of a powerful permanent magnet made of separately magnetised laminæ superposed upon one another (as suggested by Scoresby and Jamin), and is thereby powerfully magnetised and directed into the horizontal plane. The coils of conducting wire are carried round the needle by being wound upon a light rectangular frame which surrounds the needle, but lies within the limbs of the permanent magnet. When a current passes the needle jumps almost instantaneously to its position of equilibrium, its oscillations being of extremely short duration. M. Deprez has also tried needles made up of several superposed layers of the thin sheet iron used in telephones, but the form shown in the figure is, on the whole, the most satisfactory in practical operation. One advantage possessed by the instrument is that it is independent of gravity and of the magnetism of the earth, and can therefore be used anywhere in any position. It will, therefore, be found to be a very convenient instrument for electrical engineers, but as its readings are not capable of being translated into values representing current-strengths by any simple trigonometrical function, sines or tangents, it would require to be graduated empirically by a process similar to the method of "calibration" adopted for ordinary galvanometers by Melloni, before it could be regarded as more than a convenient galvanoscope.

PROF. W. H. MILLER

It is only just to the memory of a man conspicuous within the circle of a not very large scientific class that more than a passing word should be spoken over his grave before the grass has grown on it.

William Hallows Miller, whose life began with the century, has lived far enough into it to experience what is a happy fate for a scientific man; he has seen the chief work of his life bear fruit; has seen the system he introduced holding its place in the face of other systems, and recognised more and more as a permanent addition to the agencies with which man may grapple with the problems that nature presents to him; he has seen it developed, but not superseded.

Crystallography was Miller's science. It had taken its first shape in the hands of Haüy in the decade of years before he was born, and in those of Weiss, of Mohs, and especially of Franz Ernst Neumann and of Grassmann, it had been receiving development during the years of Miller's growth and manhood.

The chair of mineralogy at Cambridge was filled previously to 1832 by Dr. Whewell, and a well-known memoir on the geometrical treatment of crystal forms which Dr. Whewell contributed to the *Transactions* of the Cambridge Philosophical Society gave an impetus to the study of crystallography in England which launched Miller on his career. For, taking this memoir and Neumann's treatise of 1823 (*Beiträge zur Krystallonomie*) as his starting point, Miller, who was a pupil of Whewell's, proceeded to develop a system of crystallography which was not published till 1838, but which was the most important work of his life.

Dr. Whewell had already for some time recognised in his pupil the ability and accuracy that marked him out for the career he afterwards pursued, and in 1832 the

historian of the inductive sciences resigned his chair and used his disinterested influence to obtain the appointment of Miller as his successor.

Previously to this, in 1825, Miller had taken his degree as a fifth wrangler, and he obtained some reputation as a tutor. In 1831 he published an elementary treatise on hydrostatics, and in 1835 one on hydrodynamics. They bore the mark of the same concise and precise treatment, and excision of all that was merely explanatory, which gave afterwards its character to his treatise on Crystallography, and probably deterred the ordinary student from that subject far more than any real difficulties inherent in the science.

Already in 1829 he had published a crystallographic notice of the forms of ammonium carbonate, followed in 1830 by two other memoirs, and thenceforward notices from time to time emanated from his pen on crystallography and on optical and physical subjects.

Miller was thirty when he succeeded to the chair, which he occupied forty-eight years.

The system of Weiss indicated the position of a face on a crystal by expressing its intercepts on a system of axes in the form of integer multiples of the intercepts (parameters) of some other selected crystal-face on the same axes.

The system of Miller represented the face by a symbol composed of three numerals, or indices, which are the denominators of three fractions with unity for their numerator and in the ratio of the multiples of the parameters; and he asserted the principle that his axes must be parallel to possible edges of the crystal.

The elegant way in which this mode of representing a face lent itself to yielding expressions for the relations between faces belonging to a zone (*i.e.* faces that would intersect in edges parallel to the same line) gave it superiority over previous methods, due to its bringing the symbols of the crystallographer into a form similar to that employed in algebraic geometry. But though expressions were given for the relations connecting four crystal planes in a zone, the principle lurking in them of the rationality of the anharmonic ratios of four such planes was not recognised, or at least was not announced as such, by Miller till 1857, nor were the further results deducible from this principle ever propounded by him. It was by a pupil of Axel Gadolin's and by V. von Lang independently that the limitations imposed by this principle on the varieties of crystal symmetry were first set forth; but Bravais had already deduced the necessity for these limitations by a parallel method of reasoning founded on the idea of what may be termed a net-pile of the centres of mass (*Raumgitter*), that is to say, a parallepipedal system of arrangement of molecules. But Miller's work consisted in working out into a beautiful system the indicial method of notation and calculation in crystallography, and obtaining expressions adapted for logarithmic computation by processes of great elegance and simplicity. The faces of a crystal he followed Neumann, Whewell, and Grassmann in representing by normals to the faces, which are conceived as all passing through a common point; and this point is taken as the centre of an imaginary sphere, the sphere of projection. The points, or poles, in which the sphere is met by these normals, and which therefore give the relative directions in space of the faces of the crystal, can have their positions on the sphere determined by the methods of spherical trigonometry. Moreover a great circle (zone circle) traversing the poles of any two faces will traverse all the poles corresponding to faces in a zone with them.

By the aid of the stereographic projection, which Miller also adopted from Neumann, he was able at once to project any of these great circles on a sheet of paper with a ruler and compasses, and for the purposes of the crystallographer elaborate edge-drawings of crystals become of comparatively little importance. Miller's system then gave expressions for working all the problems that a crystal can present, and it gave them in a form that appealed at once to the sense of symmetry and appropriateness of the mathematician.

His book at length became recognised by physicists and by the higher school of crystallography as one to supersede what had gone before it, as is evidenced by its having been translated into French by no less a man than Senarmont, into German by Grailich, who added a valuable chapter to it on crystallographic physics, and into Italian by Quintino Sella, and by its being now almost universally employed in crystallographic physics.

The future development of crystallography, there can be little doubt, will follow on the lines laid down by Miller, whatever may be the direction that development will take; and in the cause of higher scientific education, it is much to be regretted that in a National School of Mining and Mineralogy like that established in Jermyn Street the elaborate and relatively clumsy system of notation introduced by Naumann should still be retained, to the exclusion of an incomparably more comprehensive and reasonable system which has at least the advantage not only of being English in its completed form, but of having been originated by mathematicians so eminent as Neumann, Grassmann, Whewell, and Miller. For it is to be borne in mind that the (so-called) system of Naumann, apart from his long superseded geometrical treatise, is nothing but a system of notation for the general forms, and not for the particular faces of a crystal, and becomes more complicated in proportion as the symmetry of the crystal is more simple, while it is entirely useless in the methods of computation, its symbols being actually converted by the modern crystallographer who uses them into the Millerian symbols on every occasion when he wishes to deduce relations between faces and the zones to which they belong.

Besides his memoirs describing the results of crystallographic measurement and certain tracts such as that on the gnomonic projection and on the crystallographic method of Grassmann, Miller published in 1863 a tract on crystallography which was, in fact, a second edition of his original treatise.

In 1852 he published his great work, for it was all his own, on Mineralogy, modestly entitled a new edition of the "Elementary Introduction to Mineralogy, by the late William Phillips," by H. J. Brooke and W. H. Miller. The publication of this severe little volume was an epoch in the science it illustrated. It contained a mass of results obtained by Miller with all his accuracy and all his patience through many years, and tabulated in his usual concise manner. It may be said to have fired the zeal and directed the general form of the greater but still uncompleted work of his friend Des Cloizeaux. It is a monument to Miller's name, though he almost expunged that name from it. Like other work of his it may be merged in the larger works of newer men, but it will not be superseded, and will always have to be referred to.

One of the great works of Miller's life was the restoration of the standards lost in the fire which destroyed the Houses of Parliament. The microscopic accuracy of his mind here had a congenial task; and another conspicuous quality of that mind had to be brought into play in devising the elaborate precautions to be taken in order that the balances and apparatus employed might be sufficiently sensitive, and at the same time absolutely accurate when considerable weights were under determination. Indeed there was no faculty for which Miller was more remarkable than this of devising readily the most simple means of making an experiment and the apparatus needed for it.

His room at the Cambridge Museum was a storehouse of such simple and almost improvised furniture, embracing forms of apparatus needed by a crystallographer and observer using optical instruments: a little heliotrope suggested to him by a crack in the window of a railway

carriage; a clock of wondrous simplicity and accuracy, the motive power of which was a drop of water, a fresh drop always waiting ready to be picked up and to give its impulse to the returning arm of the escapement; a goniometer, consisting solely of a block of wood with a straight edge, and an upright wire with its end bent round so as to carry a cork with a second wire on which the crystal was fastened, and by which it was adjusted for measurement on Wollaston's method, the angle between two positions of the straight edge being found by the aid of a pair of compasses and determined by a continued fraction. These are a few only of the marvels of ingenuity which every one admitted to that interesting room will remember; and there were implements of observation fashioned out of the simplest materials—deal, cork, glass tube, wire—by the hand of their inventor, rough to look at, but exact in their performance. Nor was there any man who better appreciated the elaborate mechanism of an important instrument; no one, for instance, who could make an afternoon at the Greenwich Observatory more interesting and suggestive alike to the instructed student and to the uninformed visitor.

Such was the work of Miller. Personally he was quiet, unobtrusive, but observant; retiring, almost shy, in his manner, but in the highest degree genial and full of cordiality when this curtain of instinctive restraint was drawn aside and you met the man himself face to face.

He was a traveller. Impelled by his old master Whewell to the study of German as necessary to a mineralogist, he spent many a long vacation in the German and Tyrolese haunts of the mineralogist, and lost no opportunity of exchanging speech and therewith winning the esteem of the masters of his science on the Continent. Most of those contemporaries he survived. Mitscherlich, Gauss (who paid him the just tribute of complimenting him with having "exactly hit the nail on the head" in his Crystallography), Dove, Gustav Rose, Haidinger, Breithaupt, Wöhler, Sartorius von Waltershausen—names many of them but yesterday of living workers, were those of silent men before Miller's grave was closed, but they and Miller had in life been united by esteem and regard, and in some cases by warm friendship.

Of the travels which thus brought friendships and new scenes home to him, and in which he acquired valuable additions to the mineral collection at Cambridge, he had other pleasant records in the sketch-books which his constant companion, Mrs. Miller, filled as they journeyed.

Those who know the broad strath of the Towey above Llandilo in Carmarthenshire will remember, near its head, in the neighbourhood of Llandovery, a pretty gentleman's seat named Velindra. This was Miller's birthplace. Here his father, Captain Francis Miller, had settled towards the close of the last century, after fighting as an officer in the English army throughout the American War of Independence, and after losing a good estate which he possessed in the Boston Government, and which he never recovered. He too came of a fighting family, and doubtless something of the independence, the reserve and gentlemanly courtesy of the crystallographer came to him through this inheritance.

The valuable collection of minerals at Cambridge was largely the fruit of Prof. Miller's long-vacation rambles. The addition to it of the collection of Mr. Brooke, presented by his son, the late Mr. Charles Brooke, was an appropriate gift, considering the illustrations Miller had so copiously drawn from that collection for the important treatise on Mineralogy, to which he modestly gave the title of an edition of Phillips' "Mineralogy," by Mr. Brooke and himself: the real authorship of all that made the book invaluable to the true mineralogist being his whose name stood last, though for ever greatest, on the title page.

Some of his later years were devoted to arranging in the New Museum at Cambridge the collection he had done so much to form. He did not live to make a catalogue of it, though Mr. Lewis, who during Prof. Miller's illness was intrusted with the duty of acting for him, has commenced the laborious work of a register, as a preliminary to a catalogue.

There have been rumours that a change would be made in the character of the chair before the appointment of a successor to Prof. Miller. Considering that but for the two mineralogical chairs at the two great universities of England the study of crystallography otherwise than as an almost childish adjunct to popular lectures on mineralogy would have been extinguished in England, it may be worth while to urge that the significance of crystallographic structure as a key to great physical problems, and probably too, when the chemists have awakened to the fact, as a key to some of the newest problems in chemistry, gives to crystallography a very considerable claim for recognition among the subjects taught in the university that produced the greatest crystallographer of our time. N. STOREY MASKELYNE

PAUL BROCA

WE regret extremely to have to announce the death of this distinguished physician and anthropologist, which took place suddenly at Paris on Thursday last. He had attended a meeting of the Senate, of which he had lately been elected a member, and died during the night in consequence of the rupture of an aneurism. He was fifty-six years of age, born at St. Foy, in the Gironde, educated for the medical profession, and became Professor of Surgical Pathology at Paris. He soon acquired a high reputation by his researches in cerebral pathology, and continued to devote himself with great zeal to hospital work and clinical teaching to the last; but it is chiefly in consequence of his having taken up the subject of anthropology that he has obtained a world-wide fame, and occupied a position which it will indeed be difficult to fill up.

Twenty years ago the science of physical or anatomical anthropology was in its infancy, and all investigations were at variance even as to the methods to be pursued in its cultivation. Broca devoted many years of unceasing activity in endeavouring to define, systematise, and perfect these methods. The thoroughness and energy with which he threw himself into any research which he undertook were marvellous, and only equalled by the clearness and facility of expression with which he communicated his results to others. His series of essays on various subjects connected with craniometry, published in successive numbers of the *Mémoires* of the Société d'Anthropologie of Paris, and the *Revue* which he founded, and his "Instructions craniologiques et craniométriques," with the introduction of numerous neat and happily chosen terms for descriptive processes, have made an immense advance in the progress of the science.

Happily Broca's perfect simplicity and amiability of character, his pure love of science for its own sake, and his readiness to help those engaged in pursuits similar to his own, have inspired with enthusiasm most of those who came in contact with him; and he has created at Paris a school which it is to be hoped will carry on the work which he inaugurated. We may take occasion to notice his scientific work in greater detail in an early number.

THE UNITED STATES WEATHER MAPS, SEPTEMBER, 1878

IN the description of the United States Weather Maps for August, 1878, attention was drawn to the fact (vol. xxii. p. 36) that in that month atmospheric pressure was under the normal over a broad belt going halfway round the globe, extending from the Rocky Mountains across the United States, the Atlantic, Europe, and thence into Asia as far as the valley of the Lena, and the